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MEASUREMENT OF LOGGING RESIDUE—

Alternative Applications of the Line Intersect Method

by

James O. Howard, *Resource Analyst*

Franklin R. Ward, *Research Technician*

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ABSTRACT

This study was initiated to test the application of the line intersect method for measuring logging residue using a systematic grid-point approach.

Results indicate that a random orientation of sample line is best for cutover areas where topography and logging create residue orientation patterns. For areas where the terrain is more gentle, a unidirectional configuration can be used. In general, estimates of residue volume within ± 15 to 20 percent of the true value can be expected in an 8-hour day. Sampling intensity required to meet various levels of precision is also given.

KEYWORDS: Logging residue, measurement, sampling.

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INTRODUCTION

Increasing interest of forest managers in the utilization and abatement of logging residues has generated the need for detailed information on the quantity and characteristics of such residue. Residue management programs require specific data for each cutover area. Conventional cruising methods such as strip or plot cruising are extremely costly for the degree of precision needed.

Adaptation of the principles of line transect sampling to the estimation of logging residues by Warren and Olsen (1964) with modifications by Van Wagner (1968) and Bailey (1970) offers a quicker and less costly method for obtaining the needed information. Bailey reported time savings of 55 percent for the line intersect method compared with conventional cruising methods. In addition to the gross volume information used in this study, other data on residue, such as percent chippable, length, and diameter, may be readily collected and compiled.

The line intersect, or line transect, method uses the length of sample line and accumulated diameters of the residue pieces intersected to develop estimates of the volume of logging residue.[1/] The line intersect method has been used in the Pacific Northwest by Howard (1971) to estimate the characteristics and average volume of logging residue for a large number of cutover tracts within ownership

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[1] The basic equation, as derived by Van Wagner, is:

$$V = \frac{\pi^2 \ \Sigma d^2}{8L}$$

where

V = cross-sectional area of residue per unit of sample line
d = diameter of residue at point of intersection, in inches
L = length of sample line, in feet.

Estimates of cubic-foot volume or weight can be readily obtained by application of appropriate conversion factors to the basic equation.

For cubic-foot volume per acre, the formula is:

$$V = \frac{\pi^2 \ \Sigma d^2}{8L} \cdot \frac{43{,}560}{144}$$

For tons per acre, the formula is:

$$W = \frac{11.65 \ S \ \Sigma d^2}{L}$$

where

S = specific gravity of wood being sampled.

classes. However, no attempt was made to obtain precise estimates for any specific tract.

The line intersect method as traditionally used for estimating residue for a cutover area (see fig. 1) has certain disadvantages. First, since each line crossing the cutover area must properly be considered as only one sampling unit, many lines are required in order to obtain an estimate with a low sampling error. As the size of the cutover area increases, the effort required to meet the specified level of precision increases rapidly. Second, statistical analysis is complicated whenever sampling lines of unequal length are encountered. This problem occurs frequently with the irregularly shaped clearcuts common in the Pacific Northwest. Finally, as is evident in figure 1, the use of a small number of sample lines leaves substantial areas of the cutover tract unsampled. This is particularly critical as the size of the cutover area increases. The wide variation in residue concentration in a cutover area indicates that a good distribution of sample units is highly desirable.

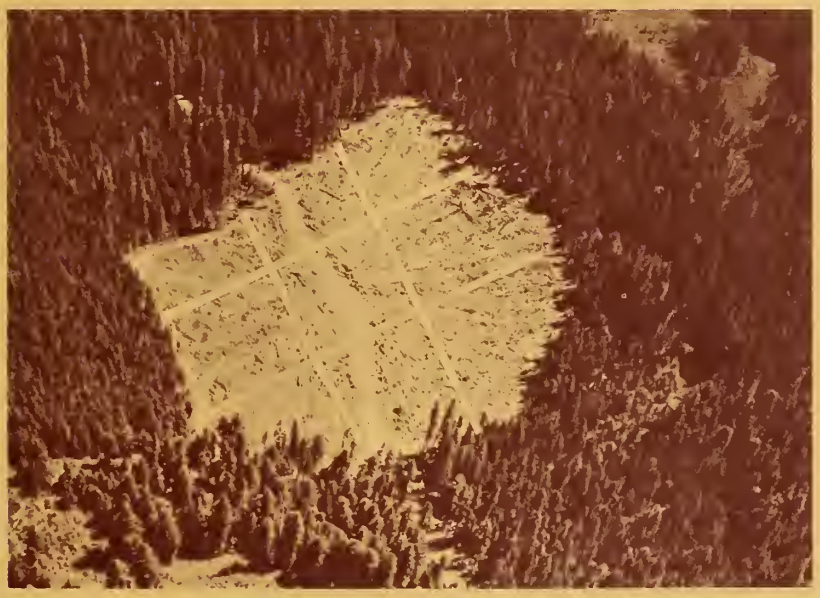

Figure 1.—Traditional application of the line intersect using two sets of continuous lines at right angles to each other. Note: each line represents one sample unit.

The search for possible solutions to these problems generated the study reported here. The purpose of the study is: to test an alternative design for applying the line intersect method to obtain estimates of residue volume for specific tracts; to develop broad guidelines for estimating the sampling intensity needed to attain various levels of precision in the estimate of residue volume; and to provide some information as to the relative precision which might be expected in a two-man, 8-hour day.

STUDY PROCEDURE

Specifically, this study was designed to test the application of the line intersect method using a systematic grid-point sampling design, with three configurations of 200-foot line segments located at each grid point.[2/] The three patterns of sample line tested are shown in figure 2. All three patterns were repeated once on each of two clearcuts, located on the Mount Hood and Willamette National Forests in western Oregon. The clearcuts selected were approximately 40 acres, with a moderate volume of residue and gently sloping, unbroken terrain. This last requirement was included to reduce the effect of topography on the concentration and orientation of the residue. On each clearcut the sample units (200-foot line segment) were located at points on a systematic grid having a 4-chain by 4-chain spacing. This grid interval was selected in order to produce about 25 sample units, a number deemed adequate for sound statistical analysis.

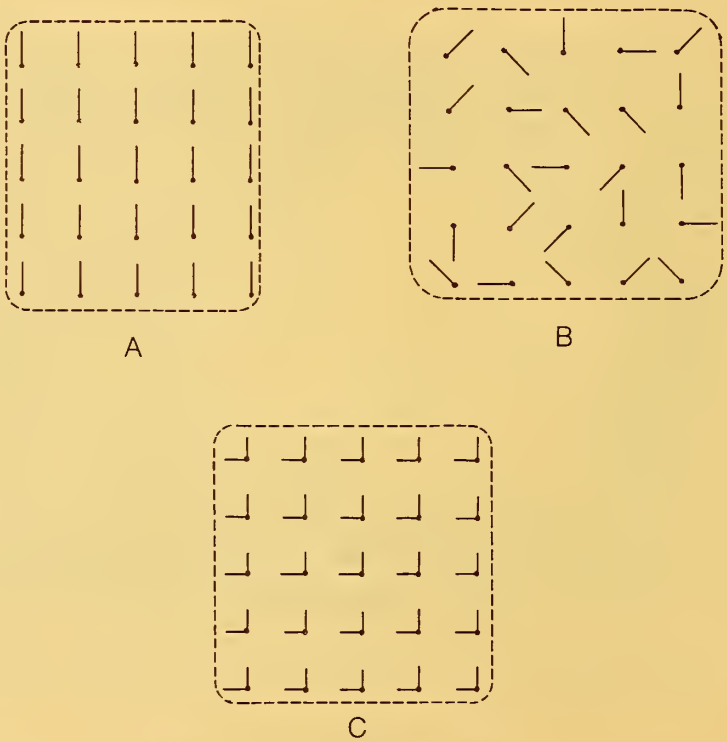

Figure 2.—Patterns of 200-foot segments tested: *A*, unidirectional pattern; *B*, randomly oriented pattern; *C*, L-shaped pattern. (Sample units located at points on a 4-chain by 4-chain grid system.)

[2] Although the use of a systematic sampling design does not lead to absolute independence of sample units, the sample observations of the three patterns of line tested are assumed to be random events and sufficiently independent for statistical analyses.

For the purposes of this study, logging residue was defined as all roundwood, except stumps and standing trees, at least 4 inches in diameter and 4 feet in length. The diameter at the point of intersection was recorded, by 1-inch class, for all residue material intersected by a sample line. These data were recorded separately for each sample unit for each of the six samples.

Working time was recorded for each of the three patterns on both clearcuts.

All lines were measured horizontally using slope corrections where necessary.

RESULTS

Table 1 shows the significant data for each of the six samples in the study. With the exception of the randomly oriented pattern on clearcut 2, each sample was completed in less than 3-1/2 hours. In both study areas, the unidirectional pattern required the least time.

Table 1.--*Sample information from line intersect technique study*

Sample design	Number of sampling units	Estimated average residue volume	Coefficient of variation	Working time[1/]	Estimated results of 8-hour day	
					Number of sampling units	Degree of precision attained[2/]
		Cu. ft. per acre	*Percent*	*Hours*		*Percent*
Clearcut 1						
Unidirectional pattern	23	3,393	78.1	2.43	76	±18
Randomly oriented pattern	23	3,611	79.1	3.08	60	±20
L-shaped pattern	23	4,298	102.0	3.18	58	±27
Clearcut 2						
Unidirectional pattern	25	4,173	88.7	2.62	76	±21
Randomly oriented pattern	25	4,322	57.3	3.65	55	±16
L-shaped pattern	25	3,802	71.4	3.32	60	±19

[1/] Two-man crew basis.

[2/] Computed sampling error at the 95-percent confidence level.

It might be noted that the high coefficient of variation associated with the L-shaped pattern on clearcut 1 was the result of a few sample units being located in a heavy concentration of residue. This is a frequent problem, where landings and broken and steep terrain tend to concentrate the residue.

The data in table 2 indicate the number of sample units required to meet various degrees of precision at the 95-percent confidence level for each of the six samples. These estimates were arrived at by use of a standard formula.[3/]

Table 2.--*Number of sample units*[1/] *needed to meet specified degree of precision*

Sample design	Degree of precision (percent)								
	±10	±15	±20	±25	±30	±35	±40	±45	±50
	Number of sampling units								
Clearcut 1									
Unidirectional pattern	235	104	59	38	26	19	15	12	9
Randomly oriented pattern	241	107	60	38	27	20	15	12	10
L-shaped pattern	400	178	100	64	44	33	25	20	16
Clearcut 2									
Unidirectional pattern	302	134	76	48	34	25	19	15	12
Randomly oriented pattern	126	56	32	20	14	10	8	6	5
L-shaped pattern	196	87	49	31	22	16	12	10	8

[1/] A sampling unit is defined as a 200-foot segment of line intersect, located at each point on a systematic grid.

[3] The formula used to compute the number of sample units is:

$$N = \frac{(C.V.)^2 \ (t)^2}{(Z)^2}$$

where

N = required number of sample units
C.V. = coefficient of variation related to each sample
t = "Student's" *t* value at the 95-percent confidence level
Z = desired degree of precision.

The variation in residue volume on a cutover area determines the sample size required for a desired level of precision. For example, in the case of the L-shaped pattern on clearcut 1 where the coefficient of variation exceeds 100 percent, 400 sample units are required to reach the 10-percent precision level. Thus it may well be that the wide variability of residue volume, coupled with the costs of measurement and the uses to which the estimates will be put, may dictate acceptance of lower standards of precision.

DISCUSSION AND CONCLUSIONS

Generally, the sampling schemes analyzed in this study obtain estimates of logging residue volume within ±15 to 20 percent of the actual volume in an 8-hour day. The results also indicate that attempts to reach precision levels of less than ±15 percent will require substantial effort.

Based on the findings of this study and previous work with the line intersect method, the randomly oriented pattern is recommended for use where cable logging is practiced, or where other variables create residue orientation bias. This bias, documented in earlier works (Warren and Olsen 1964, Van Wagner 1968, Bailey 1970), is simply the angular orientation of residue in one direction, resulting from cable yarding, slope, or downhill skidding. The straight line pattern should not be used in areas with these characteristics.

Any of the three patterns tested may be used where residue orientation bias is nonexistent, such as on flat terrain where tractor logging is practiced. The general randomness of residue dispersion for these areas was substantiated by Warren and Olsen (1964). On these types of cutover areas, the unidirectional pattern is recommended primarily because of its distinct time advantage.

In this study the sensitivity of the sampling error to changes in the length of line intersect per sample unit was not tested. It is possible that length of sample line greater than 200 feet might yield lower sampling errors.

The systematic grid-point system of locating sample units of line intersect offers a simple and efficient method for obtaining reliable estimates of logging residue volume for a specific cutover tract. A random orientation pattern of sample lines appears to be the best approach, particularly in the Douglas-fir region where cable-logged clearcuts are common.

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